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Research paper

Iris Pigment Spots Detection implementing Thresholding Method

Mustafa Man[1], Mohamad Faizal Ab Jabal[2*], Mohd Shafry Mohd Rahim[3], Suhardi Hamid[4], Wan Nural Jawahir Wan Yussof[5]

1, 5 School of Informatics and Applied Mathematics, University Malaysia Terengganu, Kuala Terengganu, Terengganu, Malaysia
2 Faculty of Computer and Mathematical Sciences, University Technology MARA Johor Branch, Pasir Gudang Campus, Johor, Malaysia*
3 School of Computing, Faculty of Engineering, UTM-IRDA Digital Media, Institute of Human Centered Engineering, University Technology of Malaysia, Johor, Malaysia
4 Faculty of Computer and Mathematical Sciences, University Technology MARA Kedah Branch, Sungai Petani Campus, Kedah, Malaysia
**Corresponding author E-mail: m.faizal@johor.uitm.edu.my*

Abstract

The increment size of the pigment spots on iris surface is indicated to the eye disease. Therefore, an automatic pigment spot detection has been proposed to detect the pigment spots on the iris surface. The main challenge is the type of feature that needs to be used for detection is unidentified. Based on the standard features applied for detection purposes, most of the features, such as shape, edges and vector, are not reliable. This situation occurs because the physical form of the pigment spots on the iris surface are dynamic. Hence, the pigment spots colour is the best feature possible to be applied, because it is moderately consistent. However, the spot colour intensity value are numerous. Several colour intensity values that have been used by other researchers were unable to detect the pigment spots. Henceforth, new colour intensity values based on thresholding method have been proposed in this paper. The approach has been applied through on the HSV colour model. The result shows the proposed values more accurate to detect the spots on the iris surface. The results have been recorded as follows (FAR) 0%, 1.33% and 4%, (FRR) 80%, 73.33%, and 70.67%, (DR) 20%, 25.33% and 25.33%.

Keywords: *Colour feature detection; HSV colour model; Iris image; Pigment spots; Threshold method*

1. Introduction

Iris recognition is a system that can be applied in various applications. The system is well accepted and used in the medical field of ophthalmology. This field is concerned with the iris, retina and eyes [12, 13, 17].

Pigment spots on the iris surface are normal occurrences in the ophthalmology. The existence of pigment spots that distort the stromal layer is known as nevi, otherwise known as freckles. Nevi is an initial symptom of eye cancer known as Uveal Melanoma (UM) [7]. There are multiple Epidemiologic reports that contribute to understanding the risk factors of UM, but the results remain inconsistent [23]. Moreover, the increase of pigment spot size may indicate an eye disease [7, 12, 13, 17]. Observing pigment spot size automatically is also proven to be futile. In addition, the dynamic form of the pigment spots on the iris surface make it very challenging for them to be detected automatically using the existing iris recognition system [12, 13]. The dynamic forms of the pigment spots on the iris surface has been defined as being varied on the shape, the position on the iris surface, and the size. Fig. 1.1 presents the sample of the pigment spots on the iris surface that are highlighted in the red circles.

It is, important to develop an automatic detection approach in order to bring about the development of the automatic iris pigment spot recognition system. The purpose of the system development is to assist the ophthalmologists **(*ophthalmology practitioners*)** in observing the pigment spots on the iris surface.

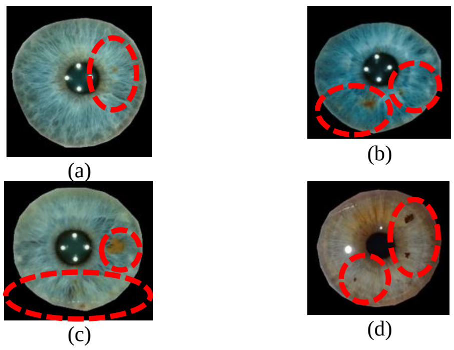


Fig. 1.1: Dynamic forms of the pigment spots on the iris surface

Therefore, the focus of this paper is to discovered a reliable thresholding intensity values to detect the pigment spots on the iris surface automatically. The output from this paper is the evaluation and findings of the detection result.

The structure of the paper is organised as follows. The presentation on the related work will be in the literature review section. The methodology section provides details of the proposed methodology. The detection performance is reported in result section. The final section concludes the paper and presents suggestions for future work.

2. Literature Review

2.1. Iris Feature

The iris contains a complex texture of visible particles of different sizes [2]. In the biological field, these particles are known as the features of the iris, which contains freckles, furrows, stripes, and coronas [2, 18]. The existence of these particles is unique from one eye to another. Previously, there have been different approaches proposed to detect the particles on the iris surface, ranging from phase-based techniques, techniques based on zero- crossings, and texture-based iris descriptors [2].

On the other hand, from the biometric perspective, there are other types of iris features typically used for identity recognition purposes. The prominent features are known as vector, binary, boundary, and edge features [1, 2, 5, 10]. In the past, there have been approaches to extract the features in order to segment the iris. The common approaches are Integro-Differential Operator algorithm, gradient-based edge detector, wavelet analysis, and Gabor filter [1, 2, 5, 10].

This study will use colour, instead of the prominent features, in order to detect the pigment spots on the iris surface. The decision has been made after considering the pigment spots dynamic forms. Only the pigment spot colour is moderately stable and thus it is possible to be used as a feature. This is because the colour of the pigment spot is nearly black or darker than the darkest brown. This is obviously a contrast to the colour of the iris where the most common colours are blue, green-hazel, or brown [7, 8, 18, 20]. Based on this reason, colour is more suitable to be used as a feature.

2.2. Colour Feature Extraction Approach

Once the iris image is determined for this study, the next step is to look into the prominent feature detection approaches that has been widely used and proposed by other researchers in iris biometric field. Daugman, the pioneer of the automatic iris recognition system had used an Integro-Differential Operator algorithm to detect the boundary feature from the iris image [1, 2, 5, 10]. Then, Wildes et. al. has applied the gradient-based edge detector to detect the edge feature and highlight the edge map on the iris image [10]. Patil and Patilkulkarni have used wavelet analysis to generate a texture feature vector in order to recognise the interest texture on iris surface [5]. In the same report, Kannavara and Bourbakis have used a local-global graph methodology in order to generate and represent the vector feature from the iris image. Since colour is the feature used in this study, the current literature does not offer any approaches from the iris biometric field that is suitably possible to be applied. However, there are several approaches from a different research field that offers a possible solution to be used in order to detect the colour from the image.

Miao et al. had proposed a method to detect the colour feature in order to classify farmland according to environmental information [15]. The method has filtered the red green blue (RGB) image into hue saturation value (HSV), hue saturation lightness (HSL) and hue saturation intensity (HSI) colour space models. But, there is no record about the name of the method used. In such cases, colour histogram is the mainstream method used by researchers to detect the colour feature [19]. Basically, the method is categorised into two categories, which are global colour histogram and local colour histogram. The global colour histogram analyses every statistical colour frequency in an image. Then the local colour histogram is focused on the specific parts of an image. In addition, the local colour histogram will consider the spatial distribution of pixel, which is lost in the global colour histogram.

Next, Johnson et al. have implemented the histogram intersection, which considered the global colour features using histogram [19]. The performance of the method has improved and it was influenced by the selection of the colour space employed such as HSV or CIELab. In the same report, the colour histogram for K means (CHKM) is another prominent method used to detect the colour feature from an image. Later, Mary and Magneta proposed to use the colour histogram method [14]. The main purpose employing the method is to compute the number of occurrence of each unique colour on an image. In a different case, Tiwari et al., employed a colour segmentation technique in order to detect ringworm psoriasis on the skin [22]. The infected part on the skin was easy to be detected by the technique because the infected region had a high density of colour contrary to the non-infected region. Furthermore, Edwards had employed CIE L*(lightness), a*(redness), b*(yellowness) colour space to extract the colour from an iris image [7]. However, the detection process was taken by using a macro in Adobe Photoshop CS5, which means no specific method was used.

In a different case, Tan and Stephen employed colour detection thresholds approach in a CIE L*a*b* colour space in order to conduct a study on the sensitivity of people to colour differences in faces and skin-coloured patches [21]. In the initial study by the authors, they claimed that the changes in a* is much easier to be detected than b* and L* in faces. However, after the experiment they concluded that the individuals are more sensitive towards the changes in the chrominance (CIELab a* and b*), but not luminance (L*), in face photographs than in skin-coloured patches. Later in Beran et al., had used the colour detection threshold approach in RGB and HSV colour space to detect objects on the chessboard [3]. The result from the experiment shows that the colour detection approach in the HSV colour space is better in detecting the objects on the chessboard compared to the RGB colour space. The advantages of the approach that it is easy to be implemented and it is possible to perform on any colour selection as long as the colour parameter is known. However, the disadvantages are the approach is sensitive with the lighting of the scene, it needs a colour template before calculations, it needs to convert from RGB to the HSV colour space, and it has a long processing time. In addition, the RGB colour space is suitable for colour display, but it is a poor choice for colour segmentation and analysis because of the high correlation among the R, G, and B components. This is a factor that influences the detection process, compared to the HSV colour that uses separate colour information. It shows that the HSV colour space is very suitable to be used for colour segmentation and analysis.

Based on the extensive discussion, it has been found that there is possibility to use the colour detection threshold approach in order to detect the colour feature of the pigment spots on the iris surface. In addition, the approach will be applied in the HSV colour space because of the stability of the colour space in the segmentation and analysis of an image. However, the values of the threshold intensity of the pigment spots are still varied in order to differentiate from the colour of the iris surface. It has become a main issue when none of the publications has discussed the threshold intensity values of the iris pigment spots and iris surface. Therefore, an experiment will be conducted in order to identify the most suitable value of the threshold intensity for pigment spots on the iris surface.

3. Testing

3.1. Methodology

The experiment has been conducted by implementing of the threshold approach through HSV colour space in order to detect the pigment spots existence on the iris surface. The methodology of the proposed approach is presented in Fig. 3.1 (**Appendix A**).

The initial process towards the image is called pre-processing. The purpose is to eliminate the irrelevant things in the image. In this case, light reflection is irrelevant and it must be eliminated in order to avoid an interruption during the detection process. Fig. 3.2 shows the steps of the elimination process.

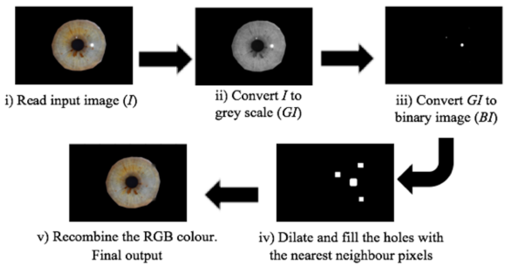


Fig. 3.2: Light reflection elimination

3.2. Proposed Approach

After receiving an input from the output of the pre-processing process, the detection process will be started with the conversion of the RGB image (*I*) into HSV colour space. The conversion process can be expressed in the algorithm as shown in (1) to (7):

$$R_n=\frac{R}{2^b};\ G_n=\frac{G}{2^b};\ B_n=\frac{B}{2^b} \tag{1}$$

Definition 3.1: R_n, G_n and B_n are normalised RGB components and the result is in range from 0 to 1. While *b* is a length of each colour component.

$$C_{max}=\max(R_n,\ G_n,B_n) \tag{2}$$

$$C_{min}=\min(R_n,\ G_n,B_n) \tag{3}$$

$$\Delta = C_{max}-C_{min} \tag{4}$$

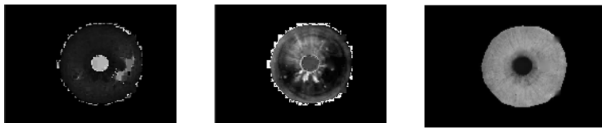
Definition 3.2: C_{max} is the maximum value from normalised RGB component. While C_{min} is the minimum value from normalised RGB component.

$$\text{Hue} = \begin{cases} 0° & \text{if } \Delta = 0 \\ 60°\cdot\left(\frac{G_n-B_n}{\Delta} \bmod 6\right) & \text{if } C_{max}=R_n \\ 60°\cdot\left(\frac{B_n-R_n}{\Delta}+2\right) & \text{if } C_{max}=G_n \\ 60°\cdot\left(\frac{R_n-G_n}{\Delta}+4\right) & \text{if } C_{max}=B_n \end{cases} \tag{5}$$

$$\text{Saturation}=\begin{cases} 0 & \text{if } C_{max}=0 \\ \frac{\Delta}{C_{max}} & \text{if } C_{max}\neq 0 \end{cases} \tag{6}$$

$$\text{Value}= C_{max} \tag{7}$$

The output from the conversion process is a set of individual images, which consists of hue, saturation, and value image as shown in the Fig. 3.3.



Hue (*H*) Saturation (*S*) Value (*V*)

Fig. 3.3: Output of the conversion process

Next, all the images are individually threshold and the algorithm can be expressed in an arithmetic equation as shown in (8). The algorithm will assign a low and high threshold intensity values for each colour band. The minimum and maximum values for every low and high threshold intensity for each colour band are in a range of 0 to 1. The low and high threshold intensity values influence the colour detection. However, knowing the algorithm is still not enough to proceed with the process because the values for low and high threshold intensity of each colour band is unknown. Further discussion will be presented in the experimental setup section.

$$f(x)=\begin{cases} \alpha_l^h & \begin{matrix} h=j \\ l=k \end{matrix} \\ \beta_l^h & \begin{matrix} h=m \\ l=n \end{matrix} \\ \gamma_l^h & \begin{matrix} h=p \\ l=q \end{matrix} \end{cases} \tag{8}$$

Definition 3.3: x is the function of set of the thresholds, α is the hue image, β is the saturation image, γ is the value image, h is the high threshold intensity value, l is the low threshold intensity value, and j, k, m, n, p, q are unknown threshold intensity values.

The next process is creating the mask for every image. The equations are as shown in (9) to (11).

$$f(\alpha_\Delta)=(\alpha_i \geq \alpha_l) \cap (\alpha_i \leq \alpha_h) \tag{9}$$

$$f(\beta_\Delta) = (\beta_i \geq \beta_l) \cap (\beta_i \leq \beta_h) \tag{10}$$

$$f(\gamma_\Delta) = (\gamma_i \geq \gamma_l) \cap (\gamma_i \leq \gamma_h) \tag{11}$$

Definition 3.4: α is the hue, β is the saturation, γ is the value, Δ is the mask, i is the image, l is the low threshold intensity value, and h is the high threshold intensity value.

The subsequent process is the filtering process where all pixels less than a certain size will be eliminated. The process can be expressed in an arithmetic equation as shown in (12) and (13). The next process is the enhancement on the image. Here the border of the object will be tidied up by using a morphological closing operation function. Then this is followed by the filling up of any holes found in the image. The final process is the presentation of the detected pigment spots.

$$f(y) = (x_i,k) \tag{12}$$

where x_i is come from (13):

$$x_i = (\alpha_\Delta \cap \beta_\Delta \cap \gamma_\Delta) \tag{13}$$

Definition 3.5: $f(y)$ is the function to eliminate the small pixels less than k pixels, x_i is the mask of the colour object, α is the hue, β is the saturation, γ is the value, Δ is the mask, and k is unknown value of pixel size.

4. Comparative Study

Miles research digital iris images are used in the conducted testing. The dataset is prepared by the Miles research company. The images have been obtained by using PV320C. The size of the images is 1749 x 1184 pixels in 256 dpi resolutions. The format of the images is in Joint Photographic Experts Group (jpeg). The images are stored in 24-bits RGB colour space [11, 12, 13, 16]. 75 images have been used in this experiment as a sample from the total 285 images.

The main purpose of conducting the experiment is to find suitable values of the threshold intensity in order to perform the thresholding process. The values of the threshold intensity are a representation of the selected colour to be detect from the image. The actual process is a conversion of the image from every HSV component into a binary image separately. Every single pixel in the image will be changed from the HSV colour values into the binary value, where all pixels that contain the selected colour value will be changed into 1 and the other values are 0. However, to proceed with the experiment, this study applied the values of the threshold intensity that has been published by ***Image Analyst*** **(*username of the person*)** in the MathWorks website as an initial step, and it can be accessed at the URL stated in the reference section [9].

Based on the threshold intensity values published by the Image Analyst, the value for $\mathrm{j, k, m, n, p, q}$ in the algorithm in (8) as presented in Table 4.1:

Table 4.1: Intensity values of colour parameters

	Yellow	Green	Red	Image Analyst [9]	Proposed
j	0.14	0.60	1.00	grayThresh (hImage)	0.20
k	0.10	0.15	0.80	0.00	0.01
m	1.00	1.00	1.00	1.00	0.90
n	0.40	0.36	0.58	grayThresh (sImage)	0.70
p	1.00	0.80	1.00	1.00	0.50
q	0.80	0.00	0.55	grayThresh (vImage)	0.01

Table 4.2: Value of the pixel size to be eliminated in the filtering process

	Image Analyst [9] (Pixel)	Proposed (Pixel)	
k	100	90	80

All the threshold intensity values will be passed into the equation (8) to perform the thresholding process. The subsequent process creates a mask of the threshold images as stated in (9) to (11). It is then followed by filtering process. In this process, the value of the parameter k stated by the Image Analyst is 100 pixels. However, the proposed value for k in this study is 80 and 90 pixels. Table 4.2 presents the proposed values for k. All values presented in Table 4.2 will be applied in (12). Every remaining area in the image after the thresholding process that has less than k value will be eliminated from the image. Then all empty areas in the image after elimination process will be filled up in the image enhancement process. The actual process will fill the empty areas with a value 0. Ultimately, the remaining area in the image is the tangible spot that is be detected.

4.1. Result Analysis

During the experiment, this study has carried out the detection result to evaluate all values in the algorithm. The comparative table shows the reliable values to be used in the algorithm in order to detect the pigment spots on the iris surface. The evaluation concerned in this testing is the correctness of all proposed values to detect the pigment spots on the iris surface. The standard performance metrics used in this study are detection rate (DR), false acceptance rate (FAR), and false rejection rate (FRR) [4, 6]. The DR is the percentage of the accurate pigment spots detected on the iris surface. While, FAR is the percentage of non-pigment spots detected as pigment spots on the iris surface. The FRR is the percentage of pigment spots fail to be detected on the iris surface. The equation for all performance metrics are shown in (14) to (16).

Table 4.3 presents the comparative study of the FAR and FRR from the conducted experiment. Based on the table, the threshold intensity values for every colour are strongly influences the pigment spots detection process. Additionally, the k value also plays an important role during the process and gives an impact to the extraction process. The extraction result is presented in the detection rate graph in Fig. 4.1. Based on the graph, the values proposed by the *Image Analyst* performed better on pigment spot detection process compared to the proposed values by this study. However, in the matter of the detection result presentation, the values proposed by this study is much better even though the detection rate is slightly less than the values proposed by the *Image Analyst*. Fig. 4.2 in **Appendix B** presents the sample extraction results.

Based on Fig. 4.2, extraction results from red and yellow are classified as FRR because there is nothing detected from the image. The green, *Image Analyst*, and as proposed by this study have detected the colour based on the threshold intensity from the algorithm. However, from the perspective of the detection result presentation, the output from the proposed values in this study is more accurate compared to green and *Image Analyst*. Yet, all outputs from the green, *Image Analyst*, and this study are not considered as successful of pigment spot detection. Referring to the original image in Fig. 4.2(a) there are no pigment spots in the image. Therefore, all output is classified as FAR because the proposed threshold intensity values are successful in detecting the intensity of the colour but are incorrect in detecting the colour of the pigment is the percentage of pigment spots fail to be detected on the iris surface. The equation for all performance metrics are shown in (14) to (16).

Fig. 4.3 in **Appendix B**, (f) is an example of a successful pigment spot detection result. The presentation of detection pigment spots also is used to classify the output as a successful detection rate (DR). Therefore, as mentioned in the previous discussion that the proposed threshold intensity values of this study are slightly less than the result compared with the *Image Analyst* in FAR, but it performed better compared with the values proposed by the *Image Analyst*, in order to detect the correct pigment spots on the iris surface as can be seen in (e) and (f) from Fig. 4.3. The finding from this result shows that the proposed intensity values by this study has a potential to perform better in order to extract the pigment spots on the iris surface. Moreover, the expected result from the finding is more accurate as showed in (f) compared with (e) in Fig. 4.3.

$$\mathrm{DR} = \frac{\text{No. of Correct Pigment Spots Detection}}{\text{Total Tested Images}} \times 100\% \quad \textbf{(14)}$$

$$\mathrm{FAR} = \frac{\text{No. of Non-Pigment Spots Detection}}{\text{Total Tested Images}} \times 100\% \quad \textbf{(15)}$$

$$\mathrm{FRR} = \frac{\text{No. of Pigment Spots Detection Error}}{\text{Total Tested Images}} \times 100\% \quad \textbf{(16)}$$

Table 4.3: Comparative study

	FAR (%)			FRR (%)		
k value	**100**	**90**	**80**	**100**	**90**	**80**
Yellow	0.0	0.0	1.3	100	100	98.7
Green	90.7	89.3	88.0	9.3	9.3	9.3

Red	0.00	0.00	0.00	100	100	100
Image Analyst	61.3	57.3	65.3	6.7	5.3	5.3
Proposed	**0.0**	**1.3**	**4.0**	**80.0**	**73.3**	**70.7**

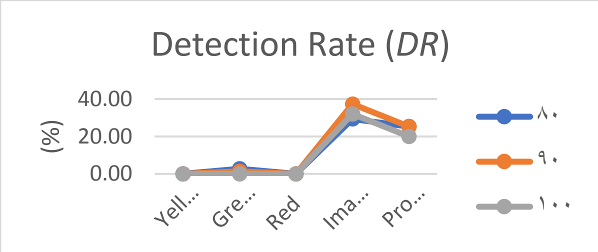


Fig. 4.1: Graph of pigment spots detection rate

5. Conclusions and Future Work

In this paper, the proposed threshold intensity values towards the colour detection threshold approach presents a better detection result compared to the existing threshold intensity values proposed by other researchers. The following conclusions can be drawn from this work.

First, thresholding method is convenient to be used for detecting the pigment spots on the iris surface. However, the existing threshold intensity values are not enough to be applied for detecting the iris pigment spots. The issue here is the pixels that are not related to the pigment spots are not eliminated from the image. Then the output produced from the detection process is inaccurate. In some cases, the produced output is completely incorrect when pigment spots were found in the image that does not contain any pigment spots on the iris surface. The solution to the issue is by proposing new threshold value sets toward pixels size in filtering algorithm. Therefore, the unnecessary pixels on the image will be considered as irrelevant pixels and eliminated.

Second, performing the thresholding process on the saturation colour space showed favourable results for the pixel colour detection. The output from the process a different colour intensity for every area on the image. Therefore, it is possible to detect the existence of the pigment spots in the image. However, the issue arises when the correct colour value of the pigment spots is unknown. In order to solve the issue, an adaptation and manipulation on the threshold intensity value on the thresholding algorithm was conducted. The result from the process is visible pigment spots have been found on the iris surface.

Thirdly, the complexity of the detection process is reduced significantly if the pigment spots pixels are masked. In order to implement the other detection methods, masking is the simplest method to detect the area of interest on the image and this will increase the detection performance. The masked image will be placed on the top of the original image and then the concerned area of the image is detected. However, the detection process depends on the thresholding and filtering process. In such cases, the detection process could not successfully determine the pigment spots in the image. Further studies will be conducted in the future in order to overcome this issue.

Finally, there are several challenges involved to detect the pigment spots on the iris surface. First, the form of the pigment spots, regardless of the shape, location and size are dynamic and very subjective. Then, the colours of the spots are fairly consistent but still different nonetheless. Therefore, this study has decided to apply the colour as a feature. Second, the colour space to use is another issue that needs tackling. After conducting several experiments, HSV is the relevant colour space to be used. Third, the values of the threshold intensity are unknown. Further continuous studies and experiments have led to the solution towards the issue. The threshold intensity values have been discovered and proposed by this study.

In conclusion, the proposed approach has successfully detected the pigment spots on the iris surface. This has proven that the thresholding method through HSV colour space is relevant to be applied in order to detect the object in an image with dynamic form. This study has highlighted that the threshold intensity value is a feature worthy to be applied.

The main finding and contribution of this study is focused on the threshold intensity value, which can be used to detect the pigment spots on the iris surface. Another finding is the value of the relevant pixel size to eliminate irrelevant pixels on the iris surface image. The final finding is the dependency of the masking process to the thresholding and filtering process leading to inaccurate detection results. This issue restrains the pigment spots detection on the iris surface as an unsolved open challenge.

Further studies and experiments will be conducted in order to improve the approach and solve the open challenge. A new algorithm will be proposed to increase the accuracy of the detection result. Therefore, a complete and accurate detection approach to detect the pigment spots on the iris surface will be proposed.

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Appendix A

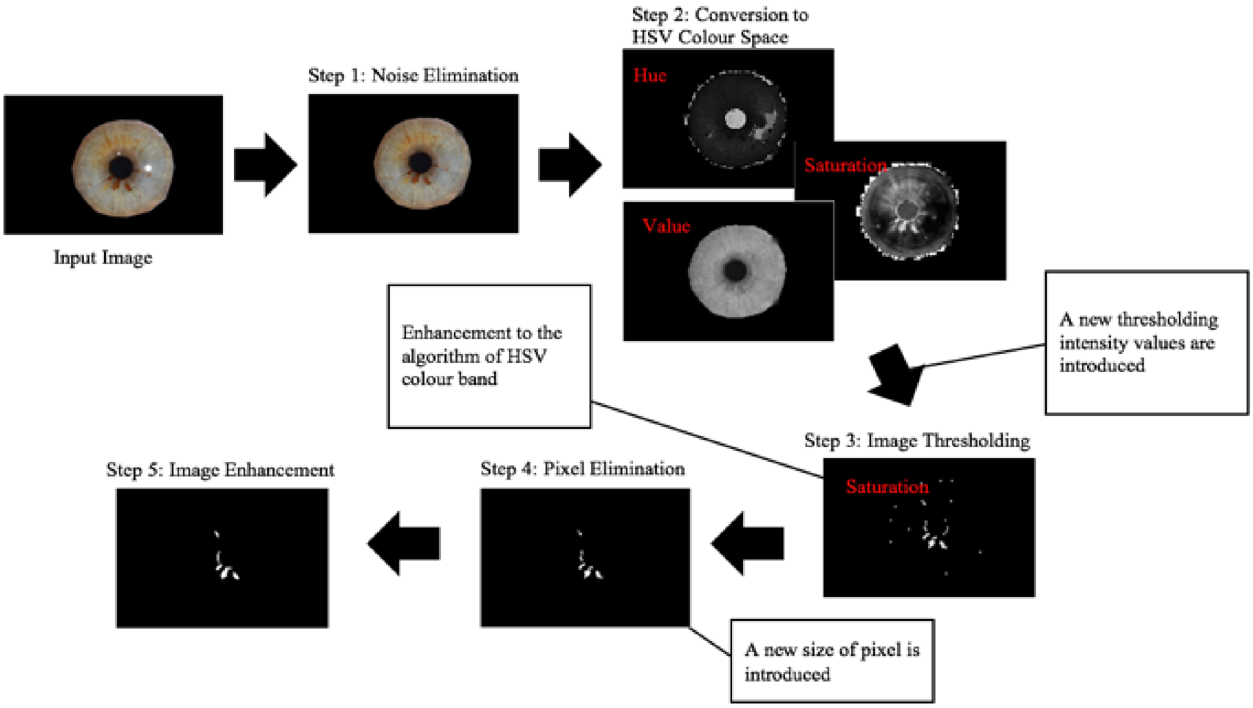
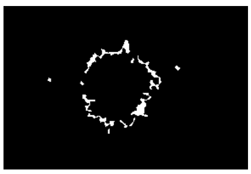


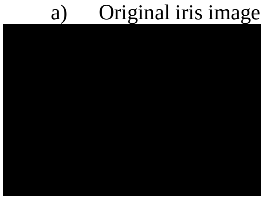
Fig. 3.1: A fundamental of the approach

Appendix B

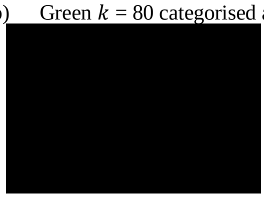
a) Original iris image



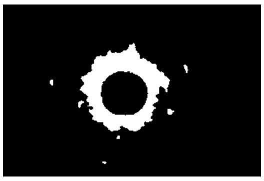
b) Green k = 80 categorised as FAR



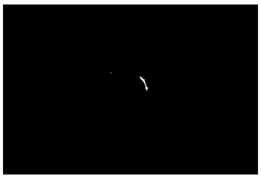
c) Red k = 80 categorised as FRR



d) Yellow k = 80 categorised as FRR

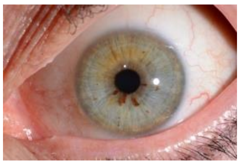


e) Image Analyst k = 80 categorised as FAR

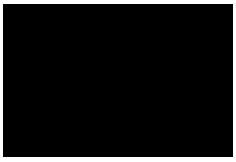


f) Proposed by this study k = 80 categorised as FAR

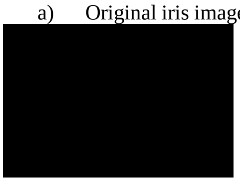
Fig. 4.2: Sample presentation of the detection result.



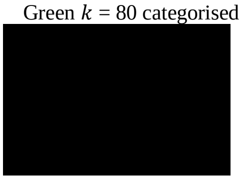
a) Original iris image



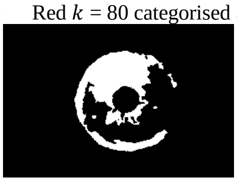
b) Green k = 80 categorised as FRR



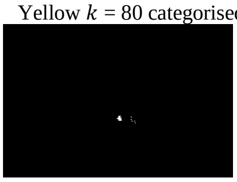
c) Red k = 80 categorised as FRR



d) Yellow k = 80 categorised as FRR



e) Image Analyst k = 80 categorised as FAR



f) Proposed by this study k = 80 categorised as DR

Fig. 4.3: Sample of the successful pigment spots detection result